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(54) HEAT TRANSFER FIN AND FIN-TUBE HEAT EXCHANGER

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Description

[0001] The present invention relates to heat transfer fins according to the preamble of claim 1, and fin-tube heat exchangers comprising such fins.

[0002] Conventionally, various types of heat transfer fins have been used for, for example, home or automobile air conditioners, freezer- refrigerators, dehumidifiers, and water heaters. Fin- tube heat exchangers, in which heat transfer fins and heat transfer tubes are combined, also are commonly used. A fin- tube heat exchanger is constructed of a plurality of heat transfer fins arranged at a predetermined fin pitch, and heat transfer tubes penetrating these fins.

[0003] In this type of heat exchanger, the heat transfer coefficient of the fin increases when the velocity of the fluid flowing over the fin surface is increased. However, as the velocity of the fluid flowing over the fin surface becomes higher, the pressure loss of the fluid that passes through the heat exchanger correspondingly increases. Thus, there is a trade-off between the pressure loss and the heat transfer coefficient in the heat exchanger. In view of this, it has been desired to improve the heat transfer coefficient and at the same time prevent the pressure loss from increasing, in order to enhance the performance of the heat exchanger.

[0004] Various fin shape designs for improving the heat transfer coefficient and reducing the pressure loss have been known. For example, JP 64-90995 A discloses a corrugated fin in which a plate-shaped fin is bent in a wave-like shape. JP 7-239196 A discloses a fin-tube heat exchanger in which a large number of very small dimples are provided on the surfaces of the fins. JP 63-294494 A discloses a fin-tube heat exchanger in which projections each having a triangular pyramidal shape are provided on the surfaces of the fins. JP 6-300474 A discloses a fin-tube heat exchanger in which quadrangular pyramidal-shaped protrusions are provided on the surfaces of the fins.

[0005] Prior art document WO 00/22366 discloses a high efficiency heat exchanger with oval tubes intended for use as a main cooling radiator within the cooling system of vehicles equipped with an internal combustion engine. The heat exchanger includes a plurality of fins which are penetrated by the oval tubes. In a space between the oval tubes a number of deflecting ports are provided which are symmetrically open and are arranged parallel to a row of the oval tubes. The deflecting ports include holes as well as parts bent from the fin forming the base plane, and a specific flow of a cooling agent is obtained. In addition, further holes are provided close to the deflecting ports and including spacers which ensure the relative centering of one fin to the neighbouring fins. The spacers can also be obtained by punching a hole into the fin and bending the punched-out elements to form the spacers.

[0006] Document DE 195 31 383 A1 discloses a heat exchanger including fins and tubes for a cooling device, wherein the fins are treated that a polygonal element in the form of a hump is obtained, having an inclined portion on one side and an open portion on the other side, the open portion forming a hole in the fin. A flow of a fluid entering a space between a plurality of fins is therefore guided so that the flow may change from one side of the fin to the other side through the opening in the hump. The cross-sectional area of the hump is opened perpendicular to the direction of flow of the fluid. This document discloses hence a fin according to the preamble of claim 1.

[0007] Prior document JP 11 166 796 A discloses a heat exchanger comprising a fin, wherein a cut is made in the fin's face which is then bent partially to provide an angle of attack and double inclination winglets having an inclination angle on the plane of the fins arranged continuously along the end face of the fin. The arrangement is provided for removing water drops on the fin.

[0008] Finally, prior art document AU 80422 75 A discloses a heat exchanger fin. In a heat exchanger a plurality of fins is provided and the fins are connected to a plurality of water tubes for providing the cooling effect. The fins include a plurality of openings each positioned between a pair of adjacent water tubes, and the openings punched into the material of the fin extend in a direction which is transverse to the direction of the flow of the fluid. The openings are provided in the form of slits for passing the fluid, and the slits are surrounded by the material of a fin in the form of an upper edge and a flat portion basically having a semicircular shape.

DISCLOSURE OF THE INVENTION

[0009] In recent years, however, further enhancements in heat exchanger performance have been desired. Accordingly, it has not always been the case that an attempt to optimize the specification of a conventional fin-tube heat exchanger can result in satisfactory performance. For this reason, a fin-tube heat exchanger that has an entirely novel fin shape has been awaited.

[0010] The present invention has been accomplished in view of the foregoing circumstances, and it is an object of the invention to provide a novel fin and a novel fin-tube heat exchanger that can improve the heat transfer coefficient and at the same time prevent the pressure loss from increasing.

[0011] According to the present invention this object is accomplished by a heat transfer fin and a fin-tube heat exchanger as set out in the appended claims.

[0012] According to the present invention, a heat transfer fin includes a protuberance protruding from a surface of the fin, and a cut-out formed upstream of the protuberance in a predetermined direction. The protuberance has, as an

upstream portion adjacent to the cut-out, a wing portion tapering toward an upstream side. The protuberance is a remaining portion after the cut-out is formed in such a manner that the wing portion is formed in an original protuberance protruding from a fin basal plane.

[0013] Hence, it is preferable that the protuberance is a remaining portion after the cut-out is formed in such a manner that the wing portion is formed in an original protuberance that is a substantially elliptical hump or a substantially circular hump protruding from a fin basal plane, and that a tangent plane to an apex of the substantially elliptical hump or the substantially circular hump be parallel to the fin basal plane. A plane containing the principal surface in which the protuberance is not formed may be defined as a fin basal plane of the heat transfer fin.

[0014] It should be noted here that the "elliptical hump" refers to a protruding portion such that the contour of its projected image obtained by orthogonal projection onto the fin basal plane is an elliptical shape and that the contour of its vertical cross section containing the apex forms a curved line (such as a sine curve or a cosine curve). On the other hand, the "circular hump" refers to a protruding portion such that the contour of its projected image obtained by orthogonal projection onto the fin basal plane is a circular shape and that the contour of its vertical cross section containing the apex forms a curved line (such as a sine curve or a cosine curve).

[0015] The protuberance may be a remaining portion after the cut-out is formed in such a manner that the wing portion is formed in an original protuberance that is a substantially elliptic cone or a substantially polygonal pyramid protruding from a fin basal plane.

[0016] Herein, the term "cone" or "pyramid" refer to a shape formed by the linear lines, each of which connects a point on the circumference of a closed curve (or angular line) on a plane (fin basal plane) with a fixed point (apex) outside the plane. The term "elliptic conic shape" refers to one in which the closed curve on the plane forms an ellipse. The term "polygonal pyramid shape" refers to one in which the closed curve on the plane forms a polygon. The term "circular cone" refers to one in which the closed curve on the plane forms a circle.

[0017] The protuberance may protrude from a fin basal plane, and the wing portion may be parallel to the fin basal plane. The triangular wing portion may slope so that its upstream side is closer to the fin basal plane. Alternatively, the triangular wing portion may slope so that its upstream side is more distant from the fin basal plane.

[0018] The heat transfer fin according to the present invention may be used for a fin-tube heat exchanger for exchanging heat between a first fluid and a second fluid. In this case, a plurality of heat transfer tube through-holes, to which heat transfer tubes for passing the second fluid are to be fitted, may be provided in the heat transfer fin at regular intervals along a predetermined row direction intersecting a flow direction of the first fluid, and further, the protuberance may be provided between two adjacent ones of the heat transfer tube through-holes. The cut-out may be formed along the wing portion of the protuberance so that, when the first fluid flowing along a principal surface of the heat transfer fin reaches the protuberance, the first fluid is allowed to flow from a first principal surface side to a second principal surface side of the heat transfer fin.

[0019] A fin-tube heat exchanger according to the present invention includes:

a plurality of heat transfer fins arranged spaced apart from and parallel to each other; and
a plurality of heat transfer tubes penetrating the heat transfer fins,
the fin-tube heat exchanger being for exchanging heat between a first fluid flowing on surfaces of the heat transfer fins and a second fluid flowing inside the heat transfer tubes, wherein:

the plurality of heat transfer tubes include a first heat transfer tube and a second heat transfer tube, both arranged in a predetermined row direction intersecting a flow direction of the first fluid;
each of the heat transfer fins has a protuberance and a cut-out between the first heat transfer tube and the second heat transfer tube, the protuberance protruding from the surface of the fin and guiding the first fluid toward the first heat transfer tube and toward the second heat transfer tube, and the cut-out being formed upstream of the protuberance with respect to the flow direction of the first fluid;
the protuberance has, as an upstream portion adjacent to the cut-out, a wing portion tapering toward an upstream side, and the protuberance is a remaining portion after the cut-out is formed in such a manner that the wing portion is formed in an original protuberance protruding from a fin basal plane.

[0020] It is preferable that the heat transfer tubes and the protuberances be arranged in a staggered manner when viewed in an axis direction of the heat transfer tubes, and the protuberances be disposed between respective ones of the heat transfer tubes that are adjacent in the row direction.

[0021] Moreover, in the fin-tube heat exchanger for exchanging heat between a first fluid and a second fluid, the cut-out is formed along a leading edge of the wing portion so that, when the first fluid flowing along a principal surface of the heat transfer fin reaches the protuberance, the first fluid is allowed to flow from a first principal surface side to a second principal surface side of the heat transfer fin;
the protuberance and the cut-out are mirror symmetrical with respect to a mirror plane of symmetry that contains a

perpendicular bisector of a line segment, the line segment connecting a center of the first heat transfer tube and a center of the second heat transfer tube at the shortest distance; and the width of the wing portion along the row direction decreases toward the upstream side with respect to the flow direction of the first fluid.

[0022] The present invention makes it possible to improve the heat transfer coefficient of the heat transfer fin and at the same time prevent the pressure loss from increasing. In addition, the present invention makes available a high performance fin-tube heat exchanger that has a novel configuration.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023]

Fig. 1 is a perspective view of a fin-tube heat exchanger.

Fig. 2A is a plan view of a fin.

Fig. 2B is a partially enlarged view of Fig. 2A.

Fig. 3 is a cross-sectional view taken along line III-III in Fig. 2A.

Fig. 4 is a front view of a portion of the fin, viewed from the upstream side.

Fig. 5 is a perspective view of the fin, illustrating the flow of air.

Fig. 6 is a plan view of a fin according to a modified example.

Fig. 7 is a plan view of a fin according to a modified example.

Fig. 8 is a plan view of a fin according to a modified example.

Fig. 9 is a plan view of a simulation model.

BEST MODE FOR CARRYING OUT THE INVENTION

[0024] Hereinbelow, embodiments of the present invention are described in detail with reference to the drawings.

[0025] As illustrated in Fig. 1, a fin-tube heat exchanger 1 according to an embodiment has a plurality of fins 3 arranged at a predetermined spacing and parallel to each other so as to form spaces for allowing air A to pass therethrough, and a plurality of heat transfer tubes 2 penetrating these fins 3. The heat exchanger 1 is for exchanging heat between the fluid flowing inside the heat transfer tubes 2 and the fluid flowing along the surfaces of the fins 3. In the present embodiment, the air A flows along the surfaces of the fins 3, and refrigerant B flows inside the heat transfer tubes 2. It should be noted that the type and state of the fluid that flows inside the heat transfer tubes 2 and those of the fluid that flows along principal surfaces of the fins 3 are not particularly limited. Each of the fluids may be either a gas or a liquid. The plurality of heat transfer tubes 2 may or may not be connected to form a single tube.

[0026] The fins 3 are formed in a substantially flat plate shape having a rectangular shape, and are arranged in the Y direction shown in the figure. In the present embodiment, the fins 3 are arranged at a regular fin pitch. The fin pitch is, for example, from 1.0 mm to 1.5 mm. The fin pitch may not necessarily be uniform, but it may be varied. It should be noted that, as illustrated in Fig. 3, fin pitch FP is defined as the distance between the centers of adjacent ones of the fins 3. An aluminum flat plate having a thickness of 0.08-0.2 mm, made by a punch-out process, for example, may be used suitably as each of the fins 3. It is preferable that the surface of the fin 3 be subjected to a hydrophobic treatment or a hydrophilic treatment, such as a boehmite treatment or coating with a hydrophilic paint.

[0027] As illustrated in Fig. 2A, two rows of the heat transfer tubes 2 are provided in the present embodiment. The heat transfer tubes 2 in each row are arranged along a longitudinal direction of the fins 3 (hereinafter simply referred to as the "Z direction" or the "row direction"). In each fin 3, a plurality of heat transfer tube through-holes, to which the heat transfer tubes 2 are fitted, are provided at regular intervals along a predetermined row direction that intersects the flow direction of the air A. Fin collars 3a are provided around the surrounding regions of the heat transfer tube through-holes. The heat transfer tubes 2 in the first row and the heat transfer tubes 2 in the second row are staggered relative to each other in the Z direction by 1/2 of the tube pitch. In other words, the heat transfer tubes 2 are arranged in a staggered manner. It should be noted that the tube pitch is represented by the distance between the centers of the heat transfer tubes 2 that are adjacent in the row direction. The outer diameter D of the heat transfer tubes 2 is, for example, from 1-20 mm. The heat transfer tubes 2 are in intimate contact with the fin collars 3a, and are fitted in the fin collars 3a. Each of the heat transfer tubes 2 may be a smooth tube, the inner surface of which is flat and smooth, or a grooved tube in which grooves are formed in the inner surface thereof.

[0028] The heat exchanger 1 is installed in such a position that the flow direction of the air A (X direction in Fig. 1) is approximately perpendicular to the stacking direction of the fins 3 (Y direction) and the row direction of the heat transfer tubes 2 (Z direction). That said, the airflow direction may be inclined slightly from the X direction as long as a sufficient heat exchange amount can be ensured.

[0029] A plurality of protuberances 5 are formed in a surface of the fin 3. Each of the protuberances 5 is formed in

such a shape that an upstream portion of an elliptical hump, which is elongated in the X direction, is partially cut off. A triangular wing portion 6 tapering toward the upstream side is formed as an upstream portion, with respect to the flow direction of the air A, of each protuberance 5. In other words, each of the protuberances 5 is formed by a rear-half portion 7 in a semi-elliptical hump shape and the triangular wing portion 6 located upstream of the rear-half portion 7. The

triangular wing portion 6 of the present embodiment is formed in what is called a delta wing shape having a substantially triangular shape. A hole (cut-out) 8 is formed upstream of the protuberance 5 so as to be adjacent to the protuberance 5. **[0030]** The hole 8 is formed along the upstream portion 6 (triangular wing portion 6), with respect to the flow direction of the air A, of the protuberance 5 so that, when the air A that flows along the principal surface of the heat transfer fin 3 reaches the protuberance 5, the air A is allowed to flow from a first principal surface side (obverse surface side) to a

second principal surface side (reverse surface side) of the heat transfer fin 3. **[0031]** The protuberance 5 protrudes from one of the surfaces of the fin 3. When one of two heat transfer tubes 2, 2 that are adjacent with respect to the Z direction, which intersects the flow direction of the air A, is defined as a first heat transfer tube 2A and the other one is defined as a second heat transfer tube 2B, only one protuberance 5 is disposed between the first heat transfer tube 2A and the second heat transfer tube 2B. Moreover, in the present embodiment, the protrusions 5 are disposed at the midpoints between the heat transfer tubes 2 that are adjacent in a row direction. More specifically, when viewed in the axis direction of the heat transfer tubes 2, the heat transfer tubes 2 are disposed in a staggered manner, and the protuberances 5 also are disposed in a staggered manner.

[0032] As will be appreciated from the partially enlarged view of Fig. 2B, the protuberance 5 and the hole 8 are mirror symmetrical with respect to a mirror plane of symmetry PS containing a perpendicular bisector of a line segment LS connecting a center C11 of the first heat transfer tube 2A and a center C21 of the second heat transfer tube 2B at the shortest distance. A boundary line BL between the protuberance 5 and the hole 8, which is observed when the fin 3 is viewed in plan, forms a protruding shape toward an upstream side with respect to the flow direction of the air A. Each of the protuberances 5 has, as the upstream portion 6 whose contour is defined by the boundary line BL, the wing portion 6 whose width along the row direction (Z direction) decreases toward the upstream side of the flow direction of the air A.

[0033] The protuberance 5 is a remaining portion of an original protuberance that is a substantially elliptical hump protruding from a fin basal plane, after the hole 8 (cut-out) is formed in the original protuberance in such a manner that the wing portion 6 is formed therein. In other words, the planer image of the protuberance 5 and the hole 8 as a whole shows an elliptical shape. The major axis of the ellipse corresponds to the X direction, and the minor axis thereof corresponds to the Z direction. In later-described other examples (see Figs. 6 and 7), the planar image of the protuberance 5 and the hole 8 shows a circular shape or a polygonal shape.

[0034] The area of the projected image of the elliptical hump 9, which becomes the foundation of the protuberance 5 (i.e., the original protuberance in which the cut-out has not yet been formed), onto the fin basal plane is set to be equal to or greater than the area of the heat transfer tube 2. In other words, the equivalent diameter d (the equivalent diameter d being defined by the equation $\pi d^2/4 = S$ (area)) of the elliptical hump 9 is equal to or greater than the outer diameter D of the heat transfer tubes 2. In the present embodiment, the longer axis of the projected image of the elliptical hump 9 is greater than the outer diameter D of the heat transfer tube 2, and the shorter axis thereof is also greater than the outer diameter D of the heat transfer tube 2. It should be noted that reference character L1 indicates the airflow-wise length (the length along the X direction) of the elliptical hump 9, and reference character L2 indicates the airflow-wise length of the protuberance 5. The fin basal plane refers to a plane containing the principal surface in which the protuberances 5 are not formed.

[0035] The center (apex) C12 of each of the elliptical humps 9 in the first row is located downstream of the center C11 of each of the heat transfer tubes 2 in the first row. On the other hand, the upstream edge 6a of each of the protuberances 5 in the first row is located upstream of the center C11 of each of the heat transfer tubes 2 in the first row. The center (apex) C22 of each of the elliptical humps 9 in the second row is located upstream of the center C21 of each of the heat transfer tubes 2 in the second row. The elliptical humps 9 in the first row and the elliptical humps 9 in the second row partially overlap with each other, when viewed in the Z direction. The protuberance 5 and the heat transfer tube 2 that are adjacent in the X direction are disposed at the same position with respect to the Z direction. Specifically, the center C12 of each of the elliptical humps 9 in the first row and the center C21 of each of the heat transfer tubes 2 in the second row are located at the same position with respect to the Z direction. Likewise, the center C11 of each of the heat transfer tubes 2 in the first row and the center (apex) C22 of each of the protuberances 5 in the second row are located at the same position with respect to the Z direction.

[0036] Thus, a portion or the entirety of the wing portion 6 is located upstream of the linear line that passes through the center C11 of the first heat transfer tube 2A and the center C21 of the second heat transfer tube 2B, with respect to the flow direction of the air A. Since the wing portion 6 is disposed in such a position, the air A can be guided to the first heat transfer tube 2A and the second heat transfer tube 2B efficiently.

[0037] In the plan view of the fin 3 shown in Fig. 2A, an angle formed by one side of the triangular wing portion 6 and the linear line parallel to the Z direction (row direction) and passing through the upstream edge 6a of the triangular wing portion 6 is defined as a sweepback angle θ . The size (area) of the triangular wing portion 6 can be adjusted by appro-

proportionately changing the sweepback angle θ . The value of the sweepback angle θ preferably may be, but is not particularly limited to, from 30 degrees to 50 degrees. In the present embodiment, it is set at about 30 degrees. In the present embodiment, the leading edge of the triangular wing portion 6 is formed linearly. However, the leading edge of the triangular wing portion 6 may be formed in a curved line. The wing portion may not have a triangular shape, but may be

other polygonal shapes, for example.

[0038] As illustrated in Fig. 3, the height H of the protuberance 5 measured from the fin basal plane 3b to the apex C12 (hereinafter simply referred to as "the height of the protuberance 5") is less than the fin pitch FP. The value of the height H of the protuberance 5 may be, but is not particularly limited to, 1/3 to 2/3 of the fin pitch FP, for example. In the present embodiment, the height H of the protuberance 5 is set at about 2/3 of the fin pitch FP

[0039] As illustrated in Fig. 3, and in Fig. 4, which is a view of the fin 3 viewed in the X direction, the triangular wing portion 6 slopes so that the distance between the triangular wing portion 6 and the fin basal plane 3b decreases toward the upstream side. In other words, the triangular wing portion 6 is formed in what is called a "head-down" condition.

[0040] A tangent plane 20 to the apex C12 of the protuberance 5 is parallel to the fin basal plane 3b. Thus, the protuberances 5 are formed in a harmonious shape with the fin basal plane 3b so as not to disturb the flow of the air needlessly.

[0041] Next, the flow of the air in the present heat exchanger 1 will be discussed.

[0042] As illustrated in Fig. 5, airflow A1 coming from the front of the fin 3 collides against the triangular wing portion 6. At this time, a thin thermal boundary layer forms over the surface of the triangular wing portion 6 due to what is called the leading edge effect. As a result, the heat transfer coefficient is improved by the triangular wing portion 6. Meanwhile, the perpendicular component of airflow (the component perpendicular to the leading edge of the triangular wing portion 6) is made smaller by the triangular wing portion 6, so the pressure loss is reduced.

[0043] Airflow A2 that has flowed over the triangular wing portion 6 subsequently flows over the rear-half portion 7 located downstream of the triangular wing portion 6. Since the triangular wing portion 6 is formed so as to divide the airflow and also the rear-half portion 7 is formed in a semi-elliptical hump shape, the airflow A2 is guided to the right and to the left by the protuberance 5. Accordingly, part of the airflow A2 is guided toward the heat transfer tube 2A side, while the other airflow A2 is guided toward the heat transfer tube 2B side. Then, the airflow A2 guided toward the heat transfer tube 2A side flows around to the rear of the heat transfer tube 2A. Likewise, the airflow A2 guided toward the heat transfer tube 2B side flows around to the rear of the heat transfer tube 2B. As a result, in a portion of the fin 3 at the rear of the heat transfer tubes 2A and 2B, the dead fluid zone is made smaller and the heat transfer coefficient is hindered from degrading.

[0044] Next, airflow A3 that has flowed around to the rear of the heat transfer tube 2A collides against the protuberance 5 in the second row. Then, by the triangular wing portion 6, the heat transfer coefficient is improved due to the leading edge effect and the pressure loss is reduced, as in the foregoing. Airflow A4 that has flowed over the triangular wing portion 6 of the protuberance 5 in the second row then flows over the rear-half portion 7 of that protuberance 5. Thereby, part of the airflow A4 is guided along the semi-elliptical hump shape of the rear-half portion 7 toward the heat transfer tube 2C side to flow around to the rear of the heat transfer tube 2C. As a result, the dead fluid zone is made smaller and the heat transfer coefficient is hindered from degrading also at the rear of the heat transfer tube 2C.

[0045] In the present embodiment, after the air is divided by the triangular wing portion 6 toward the one heat transfer tube 2A side and toward the other heat transfer tube 2B side, the flow of the air is accelerated in the space between the rear-half portion 7 of the protuberance 5 and each of the heat transfer tubes 2A and 2B. Therefore, the heat transfer coefficient of the fin 3 improves corresponding to the acceleration of the air.

[0046] In addition, the accelerated air collides against the protuberance 5 provided downstream. As a result, the thermal boundary layer becomes thinner at the triangular wing portion 6 of the downstream protuberance 5. Accordingly, the heat transfer coefficient at the protuberance 5 of the more downstream side improves, leading to an improvement in the heat transfer coefficient of the fin 3 as a whole.

[0047] In addition, in the present heat exchanger 1, only one protuberance 5 is formed between the first heat transfer tube 2A and the second heat transfer tube 2B. The equivalent diameter d of the projected image of the elliptical hump 9 (original protuberance), which becomes the foundation of the protuberance 5, is equal to or greater than the outer diameter D of the heat transfer tube 2, which means that each protuberance 5 is formed to be relatively large. Therefore, the flow direction can be changed at a relatively large extent. Accordingly, it is possible to guide the air to the rear of the heat transfer tubes 2 desirably even when the flow velocity of the air is relatively small (for example, when the front velocity is less than 2 m/s), or even when it is particularly small (for example, when the front velocity is less than 1 m/s). The present heat exchanger 1 can exhibit good heat transfer characteristics even for the airflow in a laminar flow condition.

[0048] Moreover, since the holes 8 are formed upstream of the protuberances 5, the amount of heat transfer from the leading most edge portion of the heat transfer fin 3 to the heat transfer tubes 2 is restricted to an appropriate degree. As a result, the heat transfer coefficient of the leading most edge portion of the heat transfer fin 3 is not likely to become locally high. Therefore, it is possible to expect the effect of preventing frost formation on the leading most edge portion of the heat transfer fin 3, when the present heat exchanger 1 is used as an evaporator. Furthermore, the degradation

in heat transfer performance resulting from the decrease in the heat transfer coefficient of the leading most edge portion of the heat transfer fin 3 can be compensated by the improvement in the heat transfer performance because of the protuberances 5. In addition, even when frost formation occurs on the leading edge portion of the tapered wing portion 6, part of the air A can pass through the holes 8. Therefore, pressure loss can be minimized.

[0049] It should be noted that the shape of the elliptical hump 9 (original protuberance), which becomes the foundation of the protuberance 5, may be such a shape that its contour forms a sine curve or a cosine curve when the elliptical hump 9 is cut along the cross section perpendicular to the Z direction. In other words, the contour of the elliptical hump 9 cut along the just-mentioned cross section may be a cosine curve represented by the equation $y = K \cos(x)$, where K is a constant. Here, x is a variable in the range $-180^\circ \leq x \leq 180^\circ$.

[0050] The shape of the original protuberance, which becomes the foundation of the protuberance 5, is not limited to the elliptical hump, but may be a circular hump (see Fig. 6) or a polygonal pyramid (see Fig. 7, which shows a quadrangular pyramid as one example of the polygonal pyramid). It also may be a circular cone, an elliptic cone, or the like. When employing a shape with a sharp-pointed apex, such as a circular cone or an elliptic cone, even better heat transfer characteristics can be obtained. On the other hand, when employing a shape with a gentle apex, such as a circular hump or an elliptical hump, the manufacturing becomes easier.

[0051] Next, a method of manufacturing the above-described fin 3 will be described below. To manufacture the fin 3, first, a mold for stamping out the triangular wing portions 6 is prepared in advance, and the mold is pressed against a fin material in a flat plate shape to carry out a pressing process. As a result, portions of the fin material are stamped out to form triangular wing portions 6 in a state before protruding. Next, a mold (also prepared in advance) for the elliptical humps 9, which become the foundation of the protuberances 5, is positioned at a predetermined position, and thereafter pressed against the above-mentioned fin material. As a result, downstream portions of the stamped-out portions are partially elevated in an substantially elliptical hump shape, whereby the protuberances 5 (the triangular wing portions 6 and the rear-half portions 7) are formed.

[0052] The foregoing fin-tube heat exchanger 1 is manufactured in the following manner. Specifically, in the fin 3 manufactured in the above-described manner, holes are provided at predetermined positions at which the heat transfer tubes 2 penetrate, and the surrounding regions of the holes are elevated to form fin collars 3a. Next, a predetermined number of the fins 3 are arranged at a predetermined fin pitch, and the heat transfer tubes 2 are inserted to the holes. Then, the heat transfer tubes 2 and the fins 3 are joined (for example, by tube-expanding joining). Thereby, the foregoing fin-tube heat exchanger 1 is manufactured.

[0053] It should be noted that all of the above-described methods of manufacturing the fin 3 and the fin-tube heat exchanger 1 are merely illustrative examples, and the manufacturing methods therefor are not limited to the above-described methods.

[0054] When the thickness of the fin 3 is small or the size of the protuberances 5 is large, there is a risk that, when producing the protuberances 5, a twist may occur in the fin material or unintentional irregularities may form in the surface of the fin material. In view of this, slits 12 may be provided in advance in the fin material as illustrated in Fig. 8 so that such twists or irregularities can be absorbed. It is preferable that the slits 12 be formed between (particularly at the midpoint between) the protuberances 5 adjacent to each other in a diagonal direction. In addition, it is preferable that the slits 12 extend in directions perpendicular to the lines connecting the apexes of the protuberances 5. By providing the slits 12 in the fin material in this way, excessive stress is not likely to occur when the mold is pressed against the fin material, so it becomes easier to form the protuberances 5 with an appropriate shape and an appropriate size.

[0055] Table 1 shows simulation results in which the fin-tube heat exchangers according to the present embodiment (see Fig. 9 for the specific configuration) are compared with a fin-tube heat exchanger having a conventional corrugated fin (a fin bent in a wave-like form; for example, see Figs. 1 and 2 in JP 64-90995 A). In this simulation, the thickness of the fin was set at 0.1 mm, the fin pitch was 1.49 mm, the outer diameter of the heat transfer tubes was 7.0 mm, and the front velocity V_{air} was 1 m/s.

[TABLE 1]

					(Ratio to corrugated fin)	
	Fin No.	Vair (m/s)	H (mm)	L (mm)	α (%)	ΔP (%)
Corrugated fin (Conventional)	No. 1	1			100	100
Elliptical hump	No. 2	1	0.765	13	108.1	84.8
Circular hump	No. 3	1	1.49	10	107.6	91.2
Circular cone	No. 4	1	0.765	13	106.3	83.3
	No. 5	1	1.49	13	108.6	86.8
Quadrangular pyramid	No. 6	1	0.765	13	103.8	89.0

[0056] Here, "Elliptical hump," "Circular hump," "Circular cone," and "Quadrangular pyramid" in the fin types represent the shapes of the original protuberances, which become the foundation of the protuberances 5. In Table 1, "Circular hump" and "Elliptical hump" denote the ones in which their contours form a sine curve and a cosine curve, respectively, when cut off along the cross section perpendicular to the Z direction.

[0057] As will be appreciated from Table 1, the fin-tube heat exchangers according to the present embodiment achieve lower pressure loss and higher heat transfer coefficients than the conventional fin-tube heat exchanger having a corrugated fin.

[0058] As described above, each of the fins 3 of the fin-tube heat exchanger 1 according to the present embodiment has the protuberances 5 and the holes 8 (cut-outs) formed upstream of the protuberances 5, and each of the protuberances 5 has, as an upstream portion adjacent to the hole 8 (cut-out), the triangular wing portion 6 tapering toward an upstream side. Therefore, an improvement in heat transfer coefficient due to the leading edge effect and a reduction in pressure loss due to the decreasing of the perpendicular component of airflow are achieved by the triangular wing portions 6. Moreover, it is possible to guide the airflow to the rear of the heat transfer tubes 2 by the protuberances 5, and to improve the heat transfer coefficient at the rear of the heat transfer tubes 2. Thus, the fin-tube heat exchanger 1 according to the present embodiment makes it possible to prevent the pressure loss from increasing and at the same time improve the heat transfer coefficient. It should be noted that although the original protuberances, which become the foundation of the protuberances 5, are formed in a substantially elliptical hump shape in the present embodiment, substantially the same advantageous effects can be obtained even when the original protuberances are formed in a substantially elliptic conic shape.

[0059] In the foregoing embodiment, each of the triangular wing portions 6 slopes so that its upstream side is closer to the fin basal plane 3b. Thereby, the flow velocity of the airflow A1 flowing over the upper face (the plus direction along the Y axis in Fig. 5) of the fin 3 is accelerated, and the effect of improving the heat transfer coefficient is obtained.

[0060] However, the triangular wing portions 6 may be parallel to the fin basal plane 3b. In other words, the line segment connecting the most upstream edge 6a of the triangular wing portion 6 and the apex C12 of the protuberance 5 may be parallel to the fin basal plane 3b. In such a case, the effect of reducing the pressure loss can be obtained because the airflow A1 passing over the triangular wing portion 6 flows smoothly.

[0061] Alternatively, each of the triangular wing portions 6 may slope so that its upstream side is more distant from the fin basal plane 3b. In such a case, the flow velocity of the airflow A1 flowing over the back surface (the minus direction along the Y axis in Fig. 5) of the fin 3 is accelerated, and the effect of improving the heat transfer coefficient is obtained.

[0062] In the present embodiment, the triangular wing portions 6 are formed for both the protuberances 5 in the first row and the protuberances 5 in the second row. However, the triangular wing portions 6 may be formed for only one of the protuberances 5 in the first row and the protuberances 5 in the second row. In other words, the other one of the protuberances 5 may be the original protuberances in an elliptical hump shape or the like, as they are, before the holes (cut-outs) are not yet formed. The triangular wing portion 6 may not be formed for some of the plurality of protuberances 5 arranged in a row direction. In other words, a protuberance 5 having a triangular wing portion 6 and a protuberance having no triangular wing portion 6 (i.e., an original protuberance) may be arranged adjacent to each other in a row direction.

[0063] The present embodiment is an embodiment in which the fin 3 is utilized as a heat transfer fin for the fin-tube heat exchanger 1. However, the applications of the fin according to the present invention are not limited to the fin-tube heat exchanger, but may be other types of heat exchangers, radiators, and condensers.

INDUSTRIAL APPLICABILITY

[0064] As has been described above, the present invention is useful for heat transfer fins and fin-tube heat exchangers provided with the fins, as well as various apparatuses provided with the fins and the heat exchangers, such as heat pump systems, hot water heaters using the systems, home or automobile air conditioners, and refrigerators.

Claims

1. A heat transfer fin comprising:

a protuberance protruding from a surface of the fin; **characterised in that** a cut-out is formed upstream of the protuberance in a predetermined direction, wherein:

the protuberance has, as an upstream portion adjacent to the cut-out, a wing portion tapering toward an upstream side; and
the protuberance is a remaining portion after the cut-out is formed in such a manner that the wing portion is formed in an original protuberance protruding from a fin basal plane.

2. The heat transfer fin according to claim 1, wherein:

the original protuberance is a substantially elliptical hump or a substantially circular hump; and
a tangent plane to an apex of the substantially elliptical hump or the substantially circular hump is parallel to the fin basal plane.

3. The heat transfer fin according to claim 1, wherein the original protuberance is a substantially elliptic cone.

4. The heat transfer fin according to claim 1, wherein the original protuberance is a substantially polygonal pyramid.

5. The heat transfer fin according to claim 1, wherein:

the protuberance protrudes from a fin basal plane; and
the wing portion is parallel to the fin basal plane.

6. The heat transfer fin according to claim 1, wherein:

the protuberance protrudes from a fin basal plane; and
the wing portion slopes so that its upstream side is closer to the fin basal plane.

7. The heat transfer fin according to claim 1, wherein:

the protuberance protrudes from a fin basal plane; and
the wing portion slopes so that its upstream side is more distant from the fin basal plane.

8. The heat transfer fin according to claim 1, wherein:

for use in a fin-tube heat exchanger for exchanging heat between a first fluid and a second fluid, a plurality of heat transfer tube through-holes to which heat transfer tubes for passing the second fluid are to be fitted are provided at regular intervals along a predetermined row direction intersecting a flow direction of the first fluid; the protuberance is provided between two adjacent ones of the heat transfer tube through-holes; and
the cut-out is formed along the wing portion of the protuberance so that, when the first fluid flowing along a principal surface of the heat transfer fin reaches the protuberance, the first fluid is allowed to flow from a first principal surface side to a second principal surface side of the heat transfer fin.

9. A fin-tube heat exchanger comprising:

a plurality of heat transfer fins according to claim 1 arranged spaced apart from and parallel to each other; and
a plurality of heat transfer tubes penetrating the heat transfer fins,

the fin-tube heat exchanger being for exchanging heat between a first fluid flowing on surfaces of the heat transfer fins and a second fluid flowing inside the heat transfer tubes, wherein:

the plurality of heat transfer tubes include a first heat transfer tube and a second heat transfer tube, both arranged in a predetermined row direction intersecting a flow direction of the first fluid;
each of the heat transfer fins has a protuberance and a cut-out between the first heat transfer tube and the second heat transfer tube, the protuberance protruding from the surface of the fin and guiding the first fluid toward the first heat transfer tube and toward the second heat transfer tube, and the cut-out being formed upstream of the protuberance with respect to the flow direction of the first fluid.

10. The fin-tube heat exchanger according to claim 9, wherein:

the heat transfer tubes and the protuberances are arranged in a staggered manner when viewed in an axis direction of the heat transfer tubes; and
the protuberances are disposed between respective ones of the heat transfer tubes that are adjacent in the row direction.

11. The fin-tube heat exchanger according to claim 9 or 10, wherein:

the cut-out is formed along a leading edge of the wing portion so that, when the first fluid flowing along a principal surface of the heat transfer fin reaches the protuberance, the first fluid is allowed to flow from a first principal surface side to a second principal surface side of the heat transfer fin;
the protuberance and the cut-out are mirror symmetrical with respect to a mirror plane of symmetry that contains a perpendicular bisector of a line segment, the line segment connecting a center of the first heat transfer tube and a center of the second heat transfer tube at the shortest distance;
and
the width of the wing portion along the row direction decreases toward the upstream side with respect to the flow direction of the first fluid.

12. The fin-tube heat exchanger according to any one of claims 9 to 11, wherein only one protuberance is formed between the first heat transfer tube and the second heat transfer tube in the row direction.

13. The fin-tube heat exchanger according to any one of claims 9 to 12, wherein a planar image of the protuberance and the cut-out as a whole shows an elliptical shape, a circular shape, or a polygonal shape.

14. The fin-tube heat exchanger according to any one of claims 9 to 13, wherein a portion or an entirety of the wing portion is located upstream of a line passing through the center of the first heat transfer tube and the center of the second heat transfer tube, with respect to the flow direction of the first fluid.

15. The heat transfer fin according to any one of claims 1 to 8, wherein the protuberance comprises:

the wing portion; and
a rear-half portion located downstream of the wing portion, the rear-half portion having a semi-hump shape, a semi cone shape, or a semi polygonal pyramid shape.

Patentansprüche

1. Wärmeübertragungsrippe umfassend:

eine Erhöhung, die von einer Oberfläche der Rippe hervorragt;
dadurch gekennzeichnet, dass
ein Ausschnitt stromaufwärts der Erhöhung in einer vorbestimmten Richtung gebildet ist, wobei:

die Erhöhung einen sich zu einer Stromaufwärts-Seite verjüngenden Flügelabschnitt aufweist, als einen Stromaufwärtsabschnitt angrenzend an den Ausschnitt; und
die Erhöhung ein Restabschnitt ist, nachdem der Ausschnitt derart gebildet ist, dass der Flügelabschnitt in

einer ursprünglichen Erhöhung gebildet ist, die von einer Rippenbasisfläche hervorragt.

2. Wärmeübertragungsrippe gemäß Anspruch 1, wobei:

die ursprüngliche Erhöhung ein im Wesentlichen elliptischer Höcker oder ein im Wesentlichen kreisförmiger Höcker ist; und
eine Tangentialebene zu einer Spitze des im Wesentlichen elliptischen Höckers oder des im Wesentlichen kreisförmigen Höckers parallel zu der Rippenbasisfläche verläuft.

3. Wärmeübertragungsrippe gemäß Anspruch 1, wobei die ursprüngliche Erhöhung ein im Wesentlichen elliptischer Kegel ist.

4. Wärmeübertragungsrippe gemäß Anspruch 1, wobei die ursprüngliche Erhöhung eine im Wesentlichen vieleckige Pyramide ist.

5. Wärmeübertragungsrippe gemäß Anspruch 1, wobei:

die Erhöhung von einer Rippenbasisfläche hervorragt; und
der Flügelabschnitt parallel zu der Rippenbasisfläche verläuft.

6. Wärmeübertragungsrippe gemäß Anspruch 1, wobei:

die Erhöhung von einer Rippenbasisfläche hervorragt; und
der Flügelabschnitt derart geneigt ist, dass sich seine Stromaufwärts-Seite näher an der Rippenbasisfläche befindet.

7. Wärmeübertragungsrippe gemäß Anspruch 1, wobei:

die Erhöhung von einer Rippenbasisfläche hervorragt; und
der Flügelabschnitt derart geneigt ist, dass sich seine Stromaufwärts-Seite weiter weg von der Rippenbasisfläche befindet.

8. Wärmeübertragungsrippe gemäß Anspruch 1, wobei:

zur Verwendung in einem Rippenrohrwärmetauscher zum Wärmetausch zwischen einem ersten Fluid und einem zweiten Fluid, eine Mehrzahl von Wärmetauscherrohrdurchgangslöchern, an die Wärmetauscherrohre zum Durchgang des zweiten Fluids angepasst sind, in regelmäßigen Abständen angeordnet sind entlang einer vorbestimmten Zeilenrichtung, die eine Fließrichtung des ersten Fluids kreuzt;
die Erhöhung zwischen zwei benachbarten Rohrwärmetauscherdurchgangslöchern angeordnet ist; und
der Ausschnitt entlang des Flügelabschnitts der Erhöhung derart gebildet ist, dass, wenn das erste Fluid, das entlang einer Hauptfläche der Wärmeübertragungsrippe fließt, die Erhöhung erreicht, dem ersten Fluid gestattet ist, von einer ersten Hauptflächenseite zu einer zweiten Hauptflächenseite der Wärmeübertragungsrippe zu fließen.

9. Rippenrohrwärmetauscher umfassend:

eine Mehrzahl von Wärmeübertragungsrippen gemäß Anspruch 1, beabstandet voneinander und parallel zueinander angeordnet, und
eine Mehrzahl von Wärmetauscherrohren, die die Wärmeübertragungsrippen durchdringen,
wobei der Rippenrohrwärmetauscher vorgesehen ist, um Wärme zu tauschen zwischen einem ersten Fluid, welches auf Oberflächen der Wärmeübertragungsrippen fließt, und einem zweiten Fluid, welches im Innern der Wärmetauscherrohre fließt, wobei:

die Mehrzahl von Wärmetauscherrohren ein erstes Wärmetauscherrohr und ein zweites Wärmetauscherrohr umfassen, die in einer vorbestimmten Zeilenrichtung angeordnet sind, die eine Fließrichtung des ersten Fluids kreuzt;
jede der Wärmeübertragungsrippen eine Erhöhung und einen Ausschnitt zwischen dem ersten Wärmetauscherrohr und dem zweiten Wärmetauscherrohr umfasst, wobei die Erhöhung von der Oberfläche der Rippe

hervorragt, und wobei die Erhöhung das erste Fluid zu dem ersten Wärmetauscherrohr und zu dem zweiten Wärmetauscherrohr leitet, und wobei der Ausschnitt stromaufwärts von der Erhöhung in Bezug auf die Fließrichtung des ersten Fluids gebildet ist.

10. Rippenrohrwärmetauscher gemäß Anspruch 9, wobei:

die Wärmetauscherrohre und die Erhöhungen gestaffelt angeordnet sind, bei Betrachtung in einer Achsenrichtung der Wärmetauscherrohre; und
die Erhöhungen zwischen den entsprechenden in der Zeilenrichtung benachbarten Wärmetauscherrohren angeordnet sind.

11. Rippenrohrwärmetauscher gemäß Anspruch 9 oder 10, wobei:

der Ausschnitt entlang einer Führungskante des Flügelabschnitts derart gebildet ist, dass, wenn das erste Fluid, das entlang einer Hauptfläche der Wärmeübertragungsrippe fließt, die Erhöhung erreicht, dem ersten Fluid gestattet ist von einer ersten Hauptflächenseite zu einer zweiten Hauptflächenseite der Wärmeübertragungsrippe zu fließen;
die Erhöhung und der Ausschnitt spiegelsymmetrisch bezüglich einer Spiegelsymmetrieebene sind, die eine Mittelsenkrechte eines Linienabschnitts umfasst, wobei der Linienabschnitt ein Zentrum des ersten Wärmetauscherrohres und ein Zentrum des zweiten Wärmetauscherrohres auf der kürzesten Verbindung miteinander verbindet; und
die Breite des Flügelabschnitts entlang der Zeilenrichtung abnimmt zur Stromaufwärtsseite bezüglich der Fließrichtung des ersten Fluids.

12. Rippenrohrwärmetauscher gemäß eines der Ansprüche 9 bis 11, wobei nur eine Erhöhung zwischen dem ersten Wärmetauscherrohr und dem zweiten Wärmetauscherrohr in der Zeilenrichtung gebildet ist.

13. Rippenrohrwärmetauscher gemäß eines der Ansprüche 9 bis 12, wobei ein Planarbild der Erhöhung und des Ausschnitts als Ganzes eine elliptische Form, eine Kreisform oder eine Vieleckform aufweist.

14. Rippenrohrwärmetauscher gemäß eines der Ansprüche 9 bis 13, wobei ein Abschnitt oder eine Gesamtheit des Flügelabschnitts stromaufwärts bezüglich einer Linie angeordnet ist, die durch das Zentrum des ersten Wärmetauscherrohres und das Zentrum des zweiten Wärmetauscherrohres verläuft, bezüglich der Fließrichtung des ersten Fluids.

15. Wärmeübertragungsrippe gemäß eines der Ansprüche 1 bis 8, wobei die Erhöhung umfasst:

den Flügelabschnitt; und
einen Rückhälftenabschnitt, der stromabwärts des Flügelabschnitts angeordnet ist, wobei der Rückhälftenabschnitt eine Halbhöckerform, eine Halbkegelform oder eine Halbvieleckpyramidenform umfasst.

Revendications

1. Ailette de transfert de chaleur comprenant :

une protubérance faisant saillie à partir d'une surface de l'ailette ; **caractérisée en ce que**
une découpe est formée en amont de la protubérance dans une direction prédéterminée, où :

la protubérance comporte, en tant que partie amont située de manière adjacente à la découpe, une partie d'aile se rétrécissant vers un côté amont ; et
la protubérance est une partie restante après la formation de la découpe de telle sorte que la partie d'aile soit formée dans une protubérance d'origine faisant saillie à partir d'un plan basal d'ailette.

2. Ailette de transfert de chaleur selon la revendication 1, dans laquelle :

la protubérance d'origine est une bosse essentiellement elliptique ou une bosse essentiellement circulaire ; et

un plan tangent à un sommet de la bosse essentiellement elliptique ou de la bosse essentiellement circulaire est parallèle au plan basal d'ailette.

- 5 3. Ailette de transfert de chaleur selon la revendication 1, dans laquelle la protubérance d'origine est un cône essentiellement elliptique.
4. Ailette de transfert de chaleur selon la revendication 1, dans laquelle la protubérance d'origine est une pyramide essentiellement polygonale.
- 10 5. Ailette de transfert de chaleur selon la revendication 1, dans laquelle :
la protubérance fait saillie à partir d'un plan basal d'ailette ; et
la partie d'aile est parallèle au plan basal d'ailette.
- 15 6. Ailette de transfert de chaleur selon la revendication 1, dans laquelle :
la protubérance fait saillie à partir d'un plan basal d'ailette ; et
la partie d'aile s'incline de sorte que son côté amont soit plus proche du plan basal d'ailette.
- 20 7. Ailette de transfert de chaleur selon la revendication 1, dans laquelle :
la protubérance fait saillie à partir d'un plan basal d'ailette ; et
la partie d'aile s'incline de sorte que son côté amont soit plus éloigné du plan basal d'ailette.
- 25 8. Ailette de transfert de chaleur selon la revendication 1, dans laquelle :
pour une utilisation dans un échangeur de chaleur à tubes à ailettes permettant un échange de chaleur entre un premier fluide et un deuxième fluide, une pluralité de trous traversants de tubes de transfert de chaleur, auxquels des tubes de transfert de chaleur permettant le passage du deuxième fluide doivent être ajustés, sont
30 prévus à des intervalles réguliers le long d'une direction de rangée prédéterminée croisant une direction d'écoulement du premier fluide ;
la protubérance est prévue entre deux trous traversants adjacents parmi les trous traversants de tubes de transfert de chaleur ; et
la découpe est formée le long de la partie d'aile de la protubérance de sorte que, lorsque le premier fluide
35 s'écoulant le long d'une surface principale de l'ailette de transfert de chaleur atteint la protubérance, le premier fluide soit autorisé à s'écouler à partir d'un premier côté de surface principale jusqu'à un deuxième côté de surface principale de l'ailette de transfert de chaleur.
- 40 9. Echangeur de chaleur à tubes à ailettes, comprenant :
une pluralité d'ailettes de transfert de chaleur selon la revendication 1 agencées en étant espacées les unes des autres et parallèles les unes aux autres,
et
une pluralité de tubes de transfert de chaleur pénétrant dans les ailettes de transfert de chaleur, l'échangeur
45 de chaleur à tubes à ailettes étant destiné à échanger de la chaleur entre un premier fluide s'écoulant sur des surfaces des ailettes de transfert de chaleur et un deuxième fluide s'écoulant à l'intérieur des tubes de transfert de chaleur, dans lequel :
la pluralité de tubes de transfert de chaleur comportent un premier tube de transfert de chaleur et un
50 deuxième tube de transfert de chaleur, les deux étant agencés dans une direction de rangée prédéterminée croisant une direction d'écoulement du premier fluide ;
chacune des ailettes de transfert de chaleur a une protubérance et une découpe entre le premier tube de transfert de chaleur et le deuxième tube de transfert de chaleur, la protubérance faisant saillie à partir de la surface de l'ailette et guidant le premier fluide vers le premier tube de transfert de chaleur et vers le
55 deuxième tube de transfert de chaleur, et la découpe étant formée en amont de la protubérance par rapport à la direction d'écoulement du premier fluide.
10. Echangeur de chaleur à tubes à ailettes selon la revendication 9, dans lequel :

les tubes de transfert de chaleur et les protubérances sont agencés de manière décalée lorsqu'ils sont vus dans une direction d'axe des tubes de transfert de chaleur ; et
les protubérances sont disposées entre des tubes respectifs parmi les tubes de transfert de chaleur qui sont adjacents dans la direction de rangée.

11. Echangeur de chaleur à tubes à ailettes selon la revendication 9 ou 10, dans lequel :

la découpe est formée le long d'un bord d'attaque de la partie d'aile de sorte que, lorsque le premier fluide s'écoulant le long d'une surface principale de l'ailette de transfert de chaleur atteint la protubérance, le premier fluide soit autorisé à s'écouler à partir d'un premier côté de surface principale jusqu'à un deuxième côté de surface principale de l'ailette de transfert de chaleur ;

la protubérance et la découpe sont symétriques par rapport à un plan de symétrie qui contient une médiatrice d'un segment de droite, le segment de droite reliant un centre du premier tube de transfert de chaleur et un centre du deuxième tube de transfert de chaleur à la distance la plus courte ;

et

la largeur de la partie d'aile le long de la direction de rangée diminue vers le côté amont par rapport à la direction d'écoulement du premier fluide.

12. Echangeur de chaleur à tubes à ailettes selon l'une quelconque des revendications 9 à 11, dans lequel une seule protubérance est formée entre le premier tube de transfert de chaleur et le deuxième tube de transfert de chaleur dans la direction de rangée.

13. Echangeur de chaleur à tubes à ailettes selon l'une quelconque des revendications 9 à 12, dans lequel une image planaire de la protubérance et de la découpe dans l'ensemble montre une forme elliptique, une forme circulaire ou une forme polygonale.

14. Echangeur de chaleur à tubes à ailettes selon l'une quelconque des revendications 9 à 13, dans lequel une partie ou une totalité de la partie d'aile est située en amont d'une ligne passant à travers le centre du premier tube de transfert de chaleur et le centre du deuxième tube de transfert de chaleur, par rapport à la direction d'écoulement du premier fluide.

15. Ailette de transfert de chaleur selon l'une quelconque des revendications 1 à 8, dans laquelle la protubérance comprend :

la partie d'aile ; et

une partie de moitié arrière située en aval de la partie d'aile, la partie de moitié arrière ayant une forme de demi-bosse, une forme de demi cône ou une forme de demi pyramide polygonale.

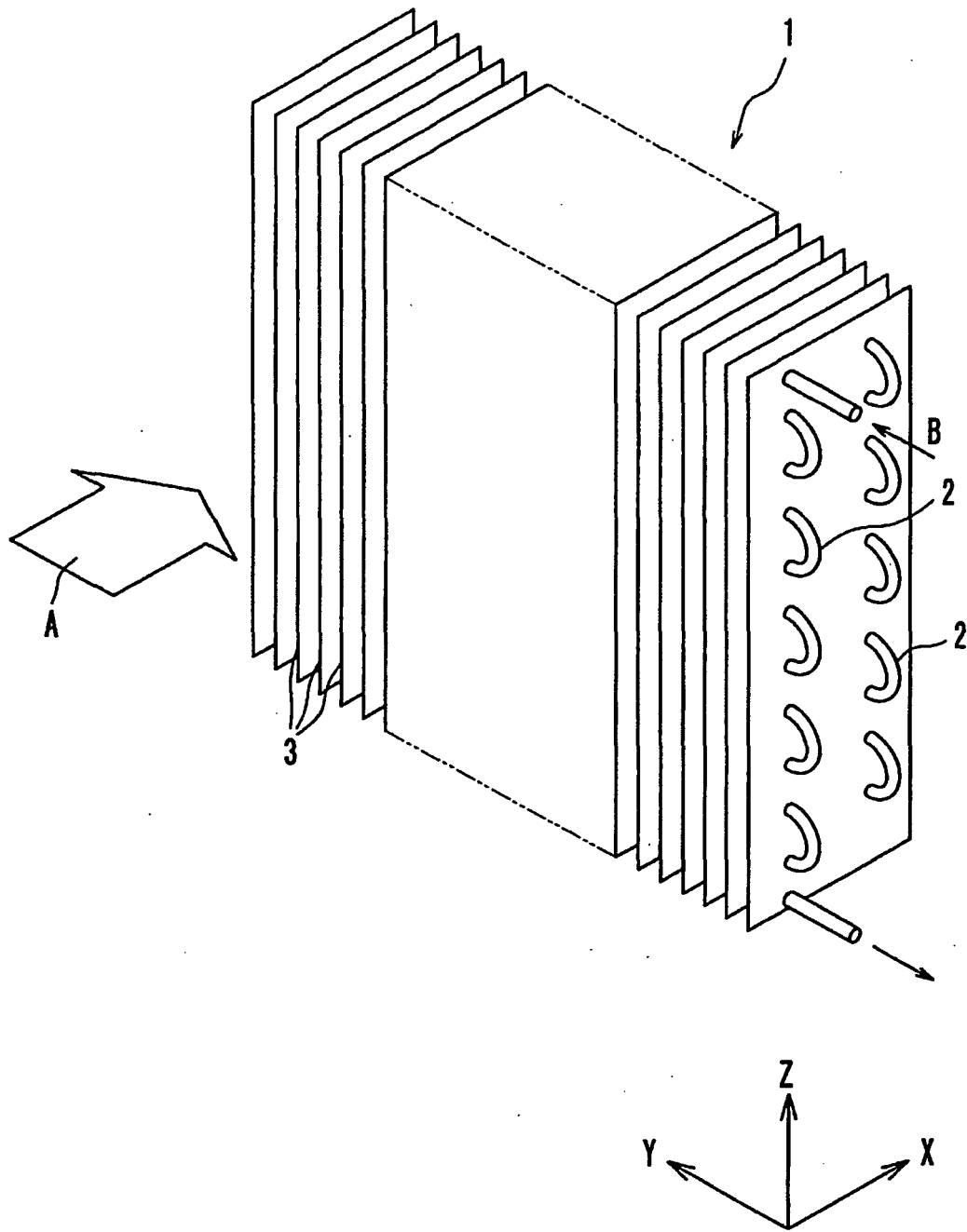


FIG.1

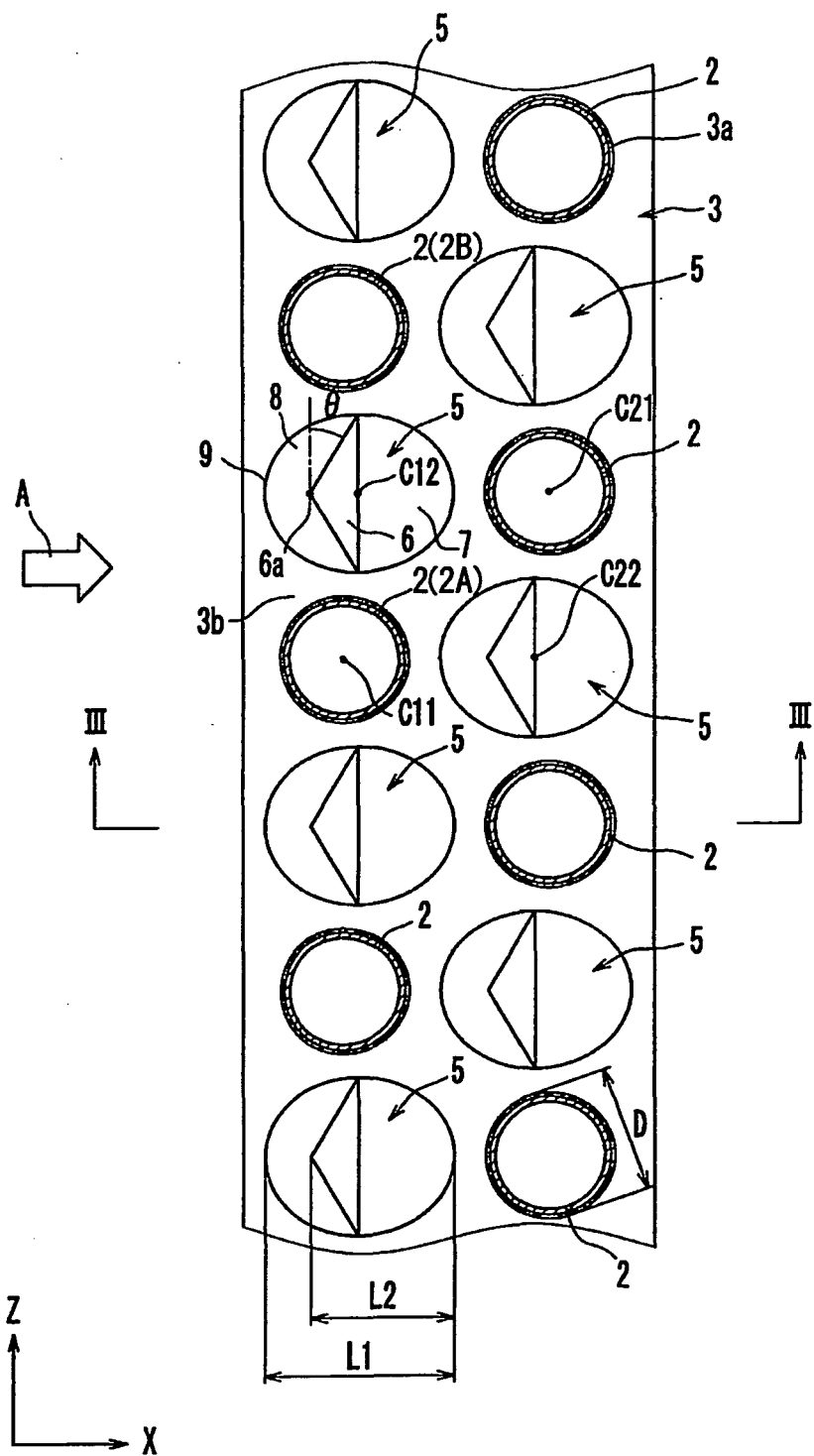


FIG.2A

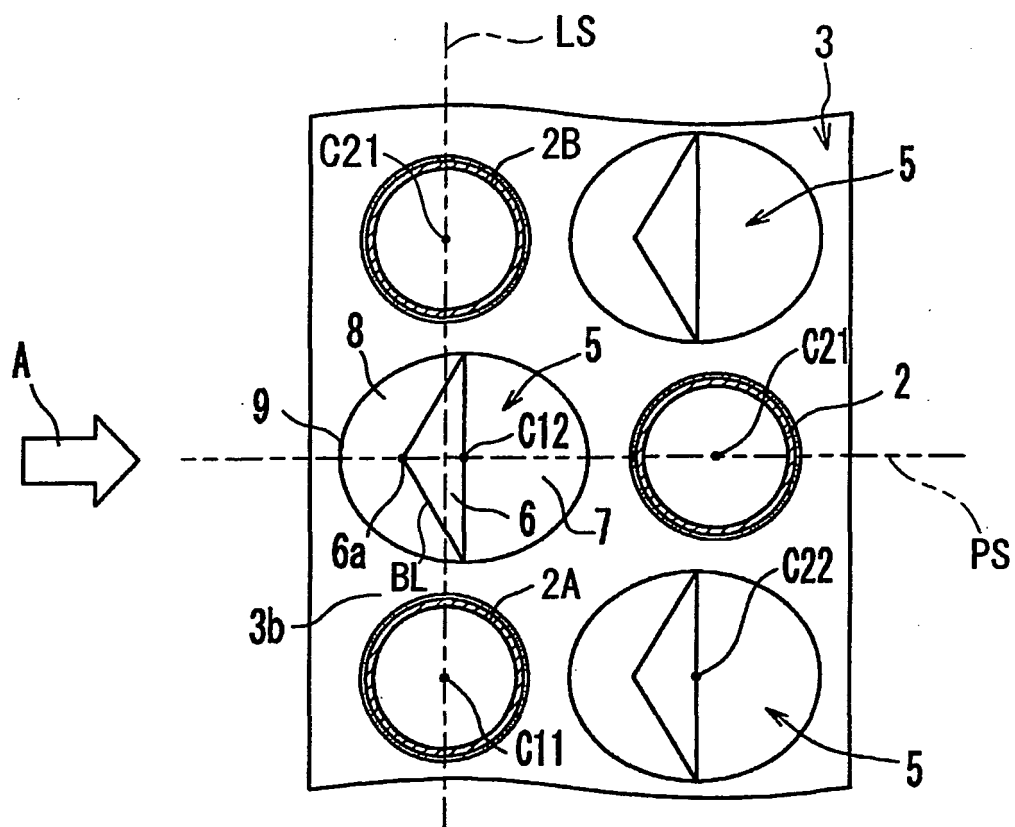


FIG. 2B

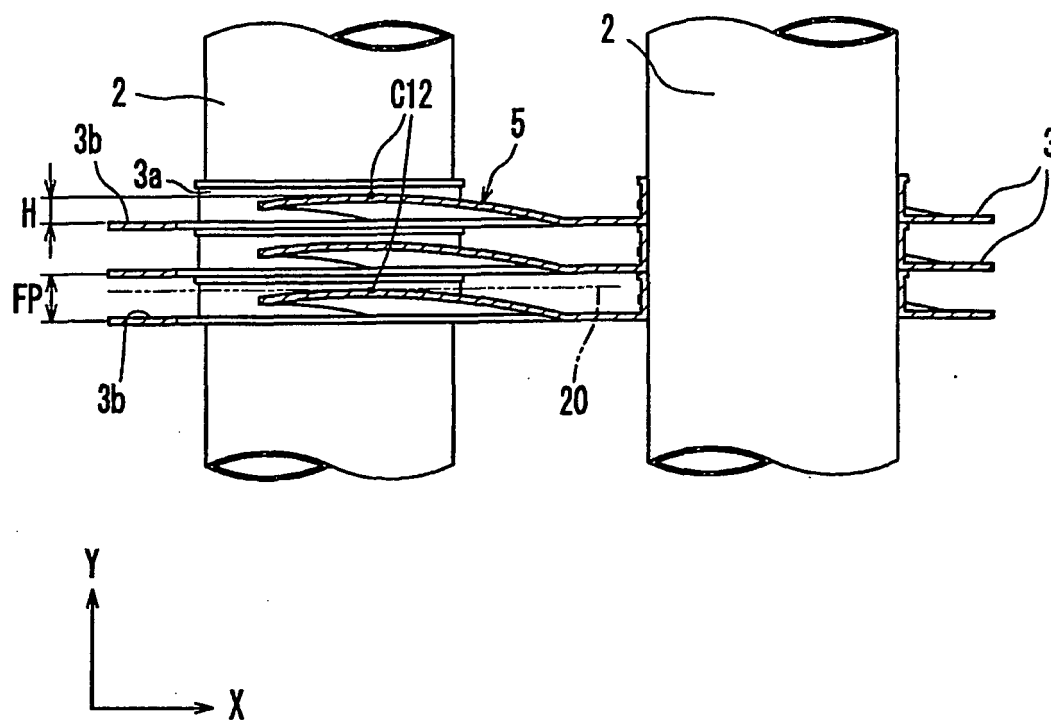


FIG.3

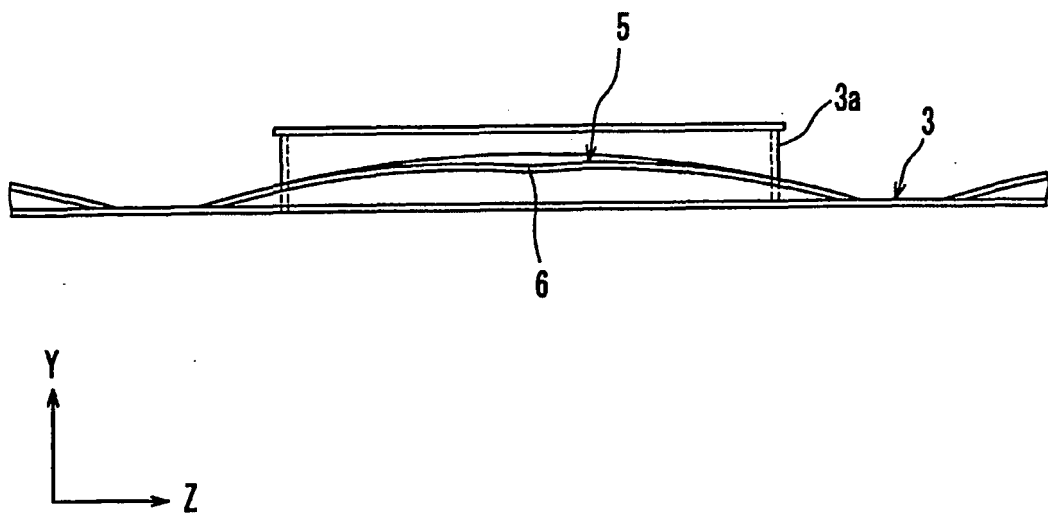


FIG.4

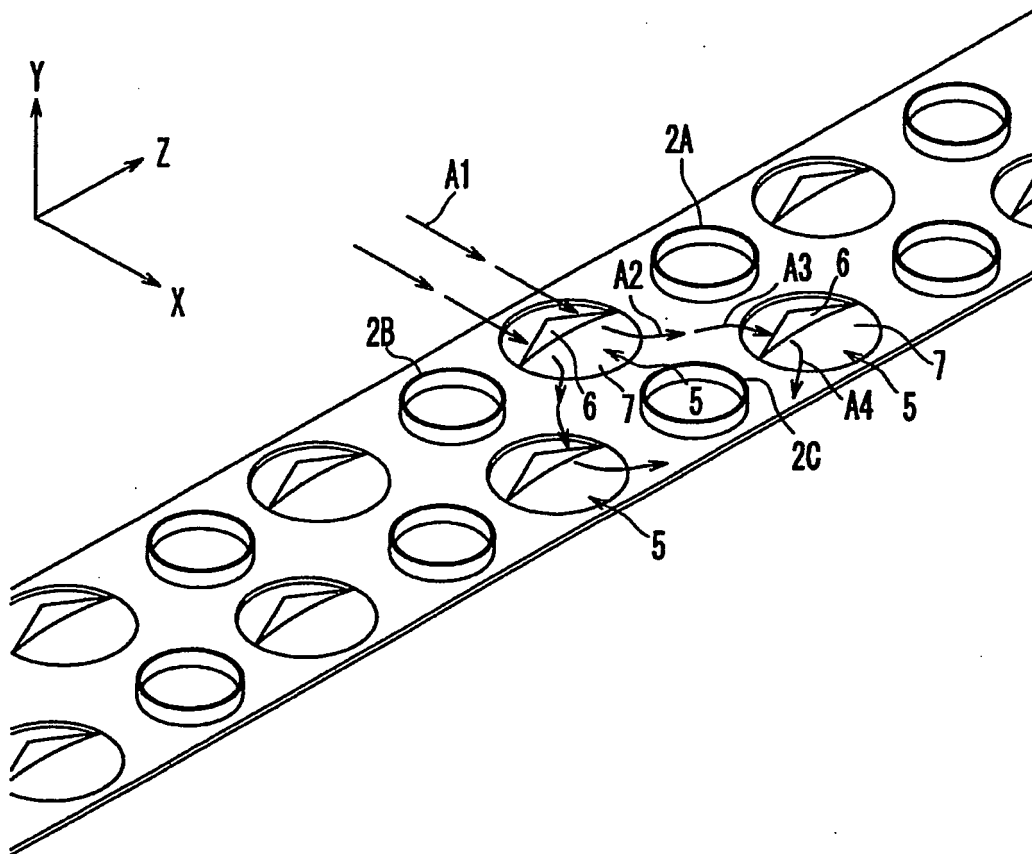


FIG.5

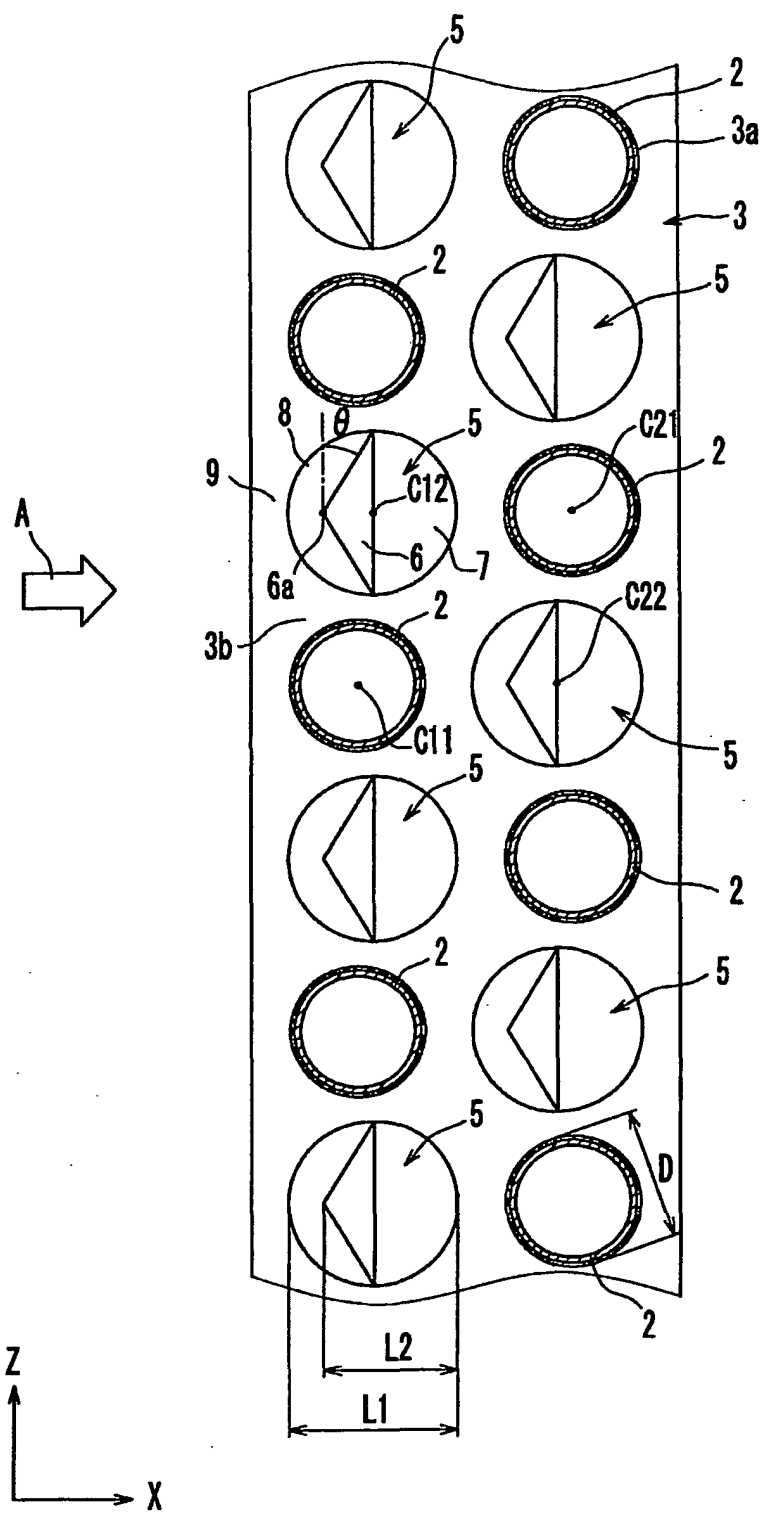


FIG.6

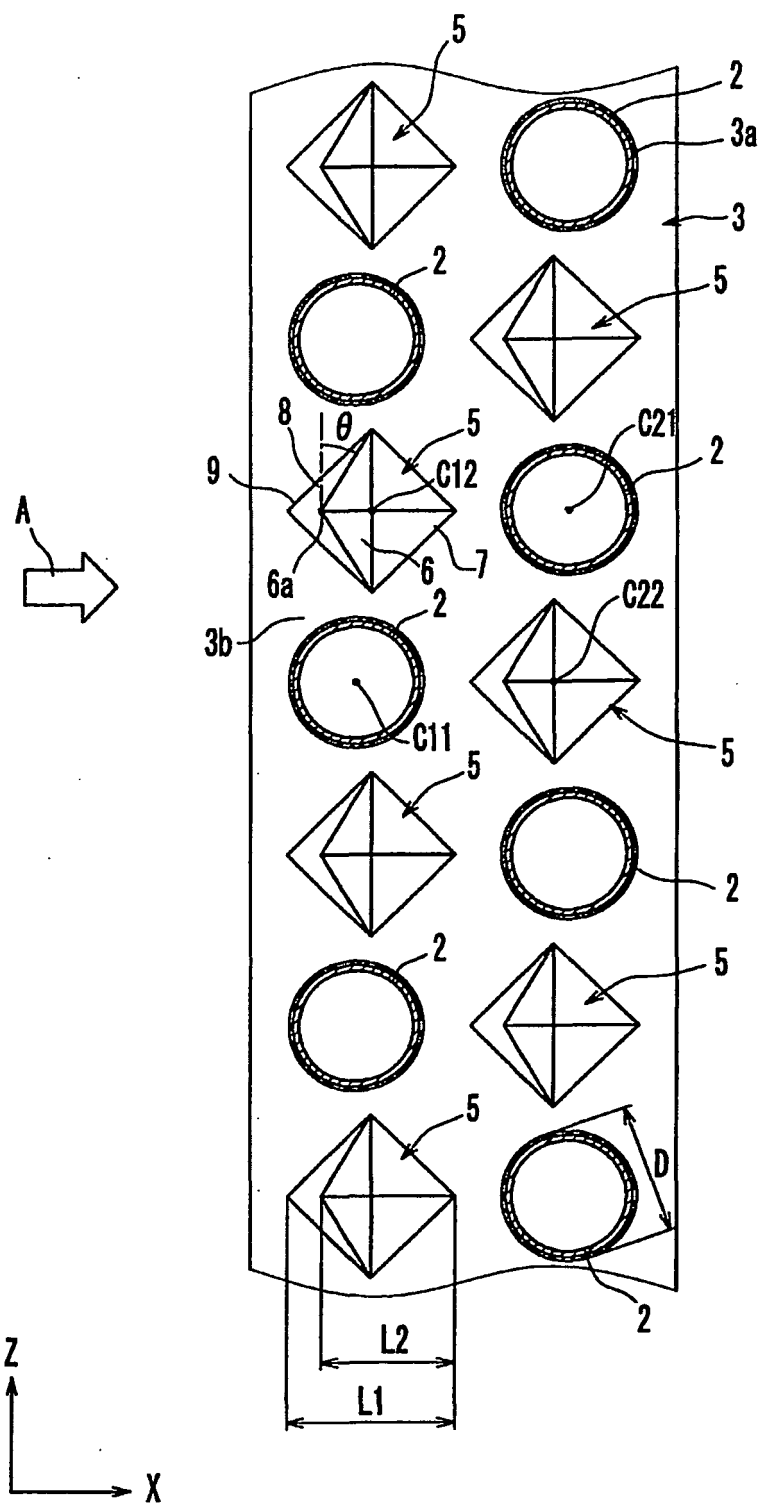


FIG.7

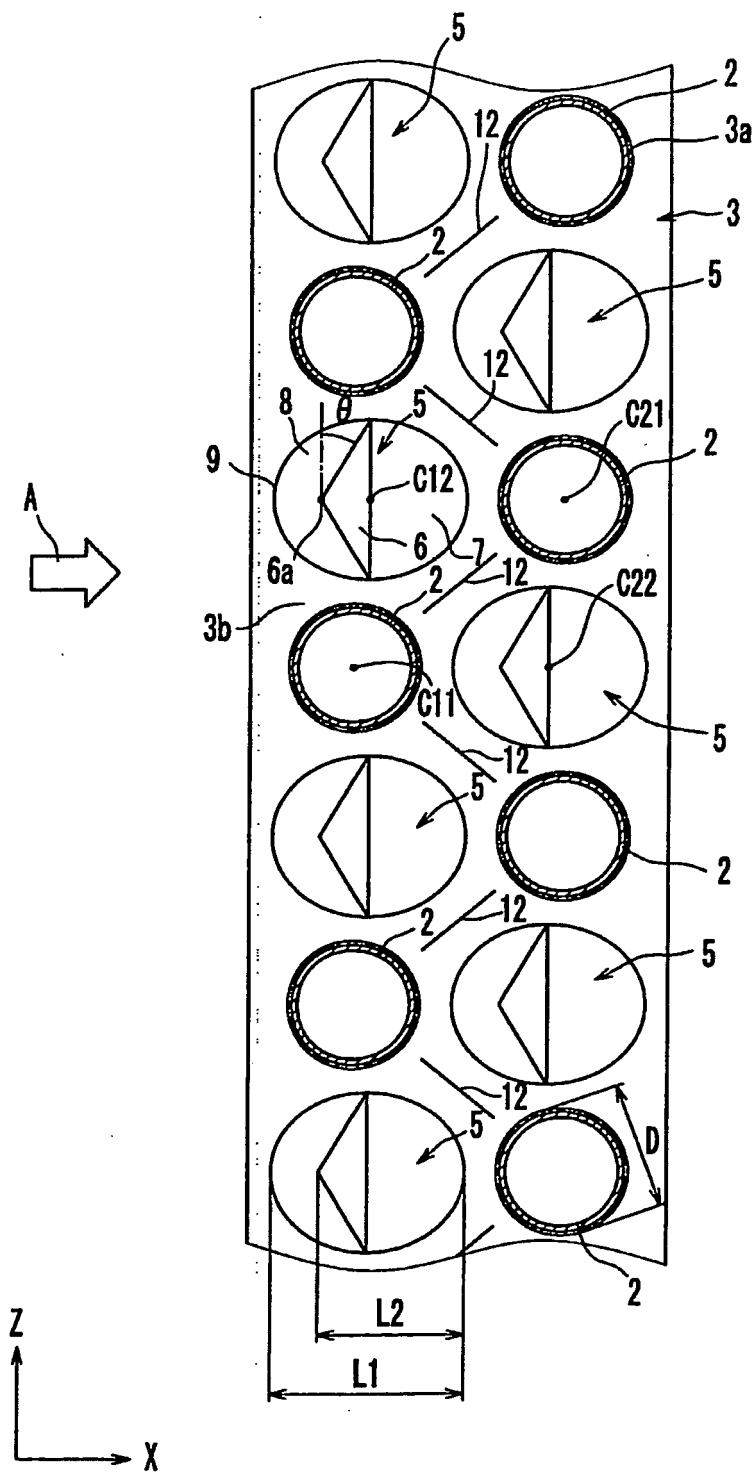


FIG.8

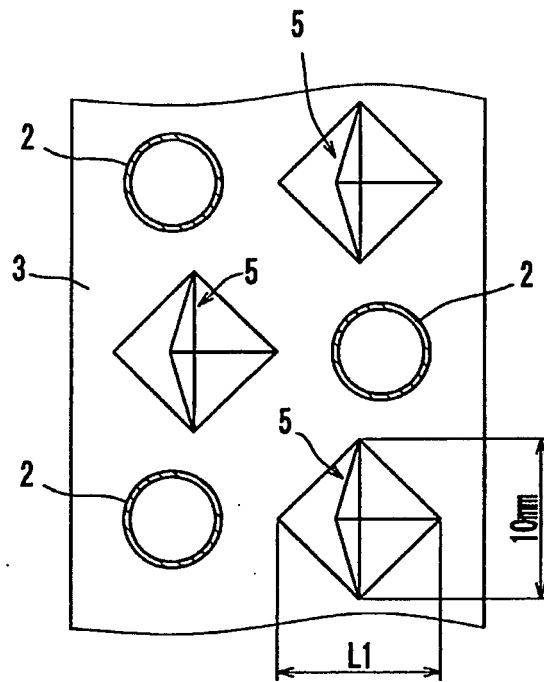


FIG.9

REFERENCES CITED IN THE DESCRIPTION

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